UDC 666.29.056.7:621.365

FORMATION OF CURRENT-CONDUCTING COATINGS BY DECALCOMANIA

E. V. Shinkareva[1] and V. V. Tavgen'[1]

Translated from *Steklo i Keramika*, No. 7, pp. 31 – 32, July, 2008.

Decalcomania is used to obtain current-conducting coatings with uniform thickness and stable electrophysical characteristics for operation of film electric heaters over a long period of time. The resistance changes after 1000 h of operation by 1.0 – 1.2% at 130 – 140°C, 1.5 – 2.0% at 160 – 170°C, and no more than 3.0% at 280 – 300°C.

The construction of film surface-distributed electric heaters is based on the use of glass enamel as the main insulation and a current-conducting element formed on the enameled surface. Schematically, a film electric heater (FEH) (Fig. 1) consists of a steel sheet covered with a glass enamel insulating layer, one side of which is covered with a current-conducting coating. The electric properties of the coatings obtained are determined by the ratio between the current-conducting filler (metal power — chromium, nickel, titanium, aluminum, and others) and an inorganic binder (low-melting glass, phosphate or silicate binder), the treatment temperature, and the thickness of the coating (USSR Inventor's Certificates Nos. 691526, 1598718, and 1466562; Belarus Patent No. 2318).

The uniformity of current-conducting coatings over their thickness depends, as a rule, on the method used to form the coatings, the most widely used method being pulverization. However, the coatings formed by this method do not have a uniform thickness: the variance of the thickness values around the average is 10 – 15% [1]. The thickness and therefore the resistance nonuniformity of the coatings make it difficult to reproduce the resistance from one sample to another, and results in temperature differentials on the surface of the FEH and accelerated failure of the heaters.

In the present work, we have studied the electrical properties of current- conducting coatings formed by decalcomania and we have determined their operating characteristics.

Low-melting barium-aluminum-borate glass (softening temperature 505°C), finely dispersed PA-VCh aluminum powder with grain size less than 40 μm, and an organic binder ordinarily used in the process of decalcomania (containing 80%[2] M-85 Tetralin (TU 6-01-958–75) and 20% A type polybutylmethacrylate resin (TU 6-10-1171–76, Belarus Patent No. 5184) were used as the initial materials for obtaining current-conducting coatings. The liquid compositions were prepared by mixing 50 – 80% organic binder with 20 – 50% of a mixture containing 20% glass and 80% PA-VCh powder. The viscosity of the compositions obtained was determined with a VZ-4 viscosimeter. The compositions prepared were deposited, through stencils made from screen fabric (GOST 3826) with cell size 0.056, 0.071, and 0.090 mm, on gummed paper and coated with AK-578T lacquer after drying.

The decals-coatings obtained on the paper comprised the blank of a heating element, consisting of eight 448 × 8 mm stripes (Fig. 2). The finished decals were deposited in the standard manner on a dielectric substrate — insulating glass enamel 12p (USSR Inventor's Certificate No. 1447762), which gave high dielectric parameters right up to the operat-

[1] State Scientific Institution "Institute of General and Inorganic Chemistry of the National Academy of Sciences of Belarus," Minsk, Belarus.

[2] Here and below — the mass content.

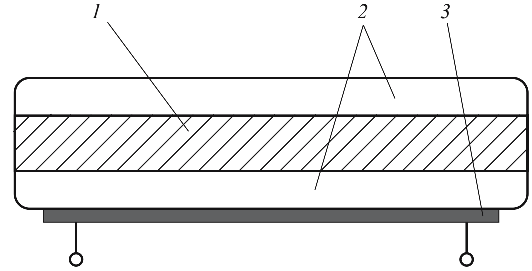

Fig. 1. Film surface-distributed electric heater: *1*) steel sheet; *2*) enamel insulating layer; *3*) current-conducting coating.

TABLE 1.

Composition	Mass ratio of the components, %		VZ-4 viscosity, cP	Properties of the composition
	organic binder	powder mixture consisting of glass and PA-VCh powder		
1	80	20	16	Liquid, seepage on the paper, poor quality decals
2	65	35	28	Uniformly deposited, high-quality decals
3	50	50	45	Dense, passes poorly through screen stencils

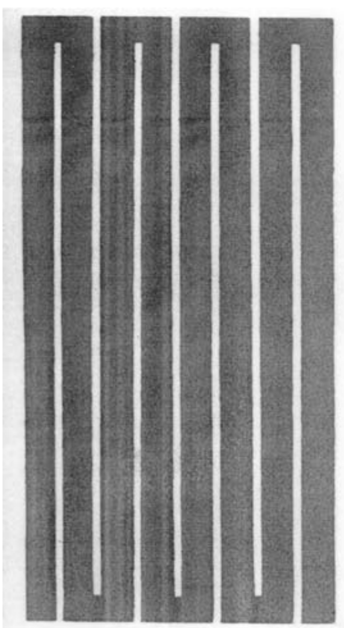

Fig. 2. Current-conducting decals-coatings formed on gummed paper and coated with AK-578T lacquer.

TABLE 2.

FEH	Cell size of the screen fabric through which a decal was formed, mm	Average coating thickness, μm	Maximum thickness deviations, %	FEH volume resistivity, Ω · cm
1	0.056	25.15	+ 0.60 – 0.60	0.070
2	0.056	25.16	+ 0.56 – 0.63	0.067
4	0.071	68.15	+ 0.51 – 0.40	0.038
5	0.071	68.21	+ 0.57 – 0.31	0.040
8	0.090	109.13	+ 0.43 – 0.30	0.011
9	0.090	109.20	+ 0.46 – 0.37	0.013

ing temperatures of FEH. The coatings were fired at 660°C for 10 – 15 min.

The electric resistance of the coatings was measured with a Shch-4300 combination unit. Copper deposited on the current-conducting coatings served as electrodes. The volume resistivity of the coatings was calculated from the relation

$$\rho_v = \frac{Rh\tau}{l},$$

where ρ_v is the volume resistivity, Ω · cm; R is total resistance of the coating, Ω; h is the track width of the coating, cm; τ is the thickness of the coating, cm; and, l is the distance between the electrodes, cm.

The thickness of the current-conducting coatings was measured with a MT-41NTs magnetic thickness meter. The temperature coefficient of the resistance was determined in temperature range 20 – 200°C.

The moisture resistance of the current-conducting coatings was determined according to the change in the resistance after the samples were boiled for 30 hours in distilled water. The stability of the electric resistance of the coatings during operation was determined by testing the electric heating elements during prolonged heating over a period of 1000 h at surface temperatures of the heater 130 – 300°C.

Investigations showed that the surface of the particles of a mixture consisting of glass and aluminum powders is well-wetted by the organic binder. The ratio of the amount of binder and powder mixture determines the viscosity of the experimental compositions (Table 1).

As one can see from the data in Table 1, the best quality decals were obtained with the composition 2, whose viscosity is 28 cP.

The fired decals-coatings adhere while to be glass enamel substrate (no cracks or delaminations). The thickness of the decals-coatings depends on the size of the cells in the screen fabric through which they were formed (Table 2).

The thickness of the current- conducting coatings can be regulated by selecting the appropriate screen fabric with definite cell size. The coatings obtained have a uniform thickness. For example, the variance of the thickness values with respect to the average is (from – 0.30 to + 0.63%), which predetermines close values of the resistance. The variance of the electric resistance between the FEH stripes is no more than 1.0%. The temperature coefficient of the resistance of the coatings is 0.112 – 0.120% · K^{-1}.

The fired coatings-decals are distinguished by good moisture resistance, and the increase of the resistance after the coatings are boiled in distilled water for 30 h does not exceed 2%. The high moisture resistance of the coatings makes it possible to use them without additional sealing.

Our investigations of the stability of the electric resistance of the coatings during heating showed that over 1000 h of operation the resistance changes by 1.0 – 1.2% at 130 – 140°C, 1.5 – 2.0% at 160 – 170°C, and no more than 3.0% at 280 – 300°C.

The current-conducting decals-coatings developed were used to fabricate experimental samples of circular water boilers by depositing decals on the lateral surface of circles. Water boiled in 2 min in a 500-W 0.4-liter electric water boiler, and the resistance of the current-conducting coating increased by 1.0 – 1.5% after 500 heating cycles.

In summary, the decalcomania method makes it possible to obtain current-conducting coatings with uniform thickness and with electrophysical characteristics which remain stable during prolonged operation of FEH. Such heating elements can be used in different sectors of the national economy (for heating rooms and water).

REFERENCES

1. L. S. Gerasimovich, *Low-Temperature Heaters in the National Economy* [in Russian], Minsk (1984).